

Pollutants in North Pacific Albatrosses¹

HARVEY I. FISHER²

ABSTRACT: Visceral fat from Black-footed Albatrosses, *Diomedea nigripes*, and Laysan Albatrosses, *D. immutabilis*, from Midway Atoll, North Pacific Ocean, in 1969 contained appreciable residues of DDT, DDE, and PCBs, and measurable quantities of DDD, dieldrin, and mercury. Greater residues in Black-footed Albatrosses may have resulted from scavenging. No gamma-emitting radionuclides were detected. No decreases in eggshell weight occurred in either species between 1910 and 1969.

THIS PAPER presents evidence of chemical pollution in albatrosses of the North Pacific Ocean and behavioral differences that may contribute to variations in the levels or residues.

Only as vagrants do the pelagic Black-footed and Laysan albatrosses (*Diomedea nigripes* and *D. immutabilis*, respectively) visit land other than small breeding islands in Leeward Hawaii (Rice and Kenyon 1962, Fisher and Fisher 1969). The birds begin to breed at 7 to 9 years, and they lay but one egg per year; 80 percent of the eggs are deposited in a 16-day period (Fisher 1969). They are restricted to the North Pacific Ocean, usually above lat. 20° N (Fisher and Fisher 1972). The primary food for both species is squid, and all food and water are obtained from the sea. Black-footed Albatrosses follow ships and swallow discarded materials. Laysan Albatrosses seldom follow ships. Individuals are long-lived; perhaps 15 percent attain an age of 20 or more years.

MATERIALS AND METHODS

Eggs were collected on Midway Atoll in early December of 1959 from nests destroyed in November by the control program of the United States Fish and Wildlife Service and in 1969 from nests deserted in late November. Shell weights for the 1902-1913 period were of eggs collected on various Leeward Hawaiian

Islands in late December, after perhaps 3-6 weeks of incubation.

The cleaned shells were stored at room temperatures for at least 1 year before being weighed. Ash weights were taken after the shells were ground and fired for 48 hours at 900° C. These temperatures probably reduced the calcium and magnesium carbonates to their respective oxides. Thus, gravimetric factors of 1.785 and 2.092, respectively, were used in computing total inorganic weights of shells, assuming a 98-percent calcium carbonate and 1-percent magnesium carbonate content (Romanoff and Romanoff 1949: 353).

Bones (humerus, femur, and coracoid) for strontium analysis were obtained on 5 December 1966 from breeding albatrosses, one Black-footed and four Laysans.

Visceral fat for determination of residues was from breeding birds killed accidentally in December 1969. The analyses in 1970, performed by the Wisconsin Alumni Research Foundation Institute of Madison, Wisconsin, followed protocols standard at that time (Pesticide Anal. Manual, Sec. 211.5, 1968). Because the first analyses showed possible polychlorobiphenyl (PCB) interference in other determinations and because PCBs were initially estimated from a single peak, with Aroclor 1254 being used as a standard, portions of several samples were hydrolyzed and reanalyzed for dichlorodiphenyldichloroethane (DDD), dichlorodiphenyltrichloroethane (DDT), and PCBs, with several PCB peaks being used. Techniques now available might well have further reduced the interference and provided a better separation of

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² School of Medicine and Department of Zoology, Southern Illinois University, Carbondale, Illinois 62901.

TABLE 1
ESTIMATED RESIDUES IN ALBATROSSES

SPECIES OF ALBATROSS	NUMBER	DDD	DDT	PCB	DDE	DIELDRIN
Before Hydrolysis						
Black-footed	7	0.95 (0.68–1.16)	3.50 (0.97–7.58)	22.3 (15.0–34.4)	13.7 (5.1–22.7)	0.11 (0.07–0.18)
Laysan	22	0.50 (0.06–0.94)	0.94 (0.44–1.96)	8.2 (0.94–16.7)	2.3 (0.33–4.77)	0.08 (0.03–0.12)
After Hydrolysis						
Black-footed	4	0.25 (0.12–0.39)	1.47 (0.97–2.27)	15.3 (7.5–21.3)	15.3 (5.1–22.7)	–
Laysan	6	0.16 (0.11–0.25)	0.47 (0.21–0.70)	6.7 (4.1–9.2)	3.6 (1.8–4.8)	–

NOTE: Residues given in parts per million in fat, wet weight.

TABLE 2
WEIGHTS OF EGGSHELLS OF THE LAYSAN ALBATROSS—1913, 1959, AND 1969

WEIGHTS	NO. SPECIMENS	MEAN (g)	RANGE (g)
Total Weight			
1902–1913	10	18.9 ± 0.85	14.9–23.1
1959	15	21.2 ± 0.58	18.3–25.4
1969	88	20.8 ± 0.19	17.3–25.6
Ash Weight			
1959	14	10.3 ± 0.23	8.9–12.1
1969	20	10.9 ± 0.21	9.4–12.8
Inorganic Weight			
1959	14	18.2	–
1969	20	19.3	–

the DDT complex. However, it was financially impossible to repeat the analyses and it was believed the determinations made did indeed show the general magnitude of the residues.

Mercury content was determined as per the method then standardized (Joint Mercury Residues Panel 1961), modified by atomic absorption spectrophotometry with boat technique. It was recognized that fat was not the best material for mercury analysis, but that was the only tissue then available.

RESULTS

Mercury in the visceral fat of four Black-footed Albatrosses averaged 0.075 ppm (0.05–

0.12) and in four Laysan Albatrosses 0.104 ppm (0.05–0.25).

No gamma-emitting radionuclides were found in the bones.

The relative presence of DDD, DDT, PCBs, 1,1-bis-4-chlorophenyl(2,2-dichloroethylene) (DDE), and dieldrin is indicated in Table 1.

Shells of Laysan eggs were not significantly different in total, ash, or inorganic weights between 1913, 1959, and 1969 (Table 2). We observed no increase in egg breakage in the 350 to 770 nests examined in each of the last 11 years. Eggshells of Black-foots declined 5 percent in total weight between 1959 and 1969 ($P = < 0.01$), but ash and inorganic weights apparently remained constant. There was no significant decrease in total shell weight between 1912 and 1969 (Table 3).

TABLE 3

WEIGHTS OF EGGSHELLS OF THE BLACK-FOOTED ALBATROSS—1912, 1959, AND 1969

WEIGHTS	NO. SPECIMENS	MEAN (g)	RANGE (g)
Total Weight			
1906-1912	10	23.7 \pm 0.48	21.3-25.7
1959	152	24.1 \pm 0.17	18.6-28.8
1969	12	22.8 \pm 0.40	19.2-25.9
Ash Weight			
1959	20	12.0 \pm 0.21	10.5-13.3
1969	12	11.5 \pm 0.33	9.7-13.3
Inorganic Weight			
1959	20	21.2	—
1969	12	20.4	—

DISCUSSION

The absence of gamma-emitting radionuclides is unexpected, since radioactive materials were reported in pelagic birds near Midway in 1965 when cesium-137 and strontium-90 levels were greatly elevated in North Pacific surface waters (T. R. Folsom et al., Scripps Institution of Oceanography, unpublished data).

The mercury content in the fat was relatively low. The interspecific difference in mean values is probably a function of a high reading in one Laysan Albatross. But the small quantities detected may be misleading. Little is known of differential accumulation of various mercury compounds in birds, but Finnish White-tailed Eagles, *Haliaeetus albicilla*, for example, exhibited great variation between tissues: kidney, 49-123 mg/kg; liver, 5-27 mg/kg; and muscle, 2-9 mg/kg (Henriksson et al. 1966). Consequently, small quantities in albatross fat may not be indicative of the loading elsewhere. Furthermore, the fat was obtained early in the breeding cycle when fat reserves were high; thus, samples later in the season would probably reveal higher percentage levels even though the total residue in the body remained constant.

The mercury may represent normal increments produced by volcanic action in the Pacific Ocean (Klein and Goldberg 1970) and concentrated by lower organisms which are most abundant where turbulence and upwelling produce fertile waters. Later decomposition of the organisms increases the mercury content in sediments of the areas, which are also albatross-feeding areas. Upwelling also increases the

speed and extent of mixing with surface waters and the sediment-to-organism cycle; thus, more rapid concentration occurs in the food web (anonymous 1970). For example, the deep waters off Japan, beneath a primary albatross-feeding area, have 0.15 to 0.27 μ g of mercury per liter; surface layers have 0.10 μ g/liter, an amount considerably higher than that recorded for most of the Pacific (Hosohara 1961 in Klein and Goldberg 1970).

The values for DDT, DDD, and PCBs after hydrolysis are considerably lower than those reported in livers of pelagic birds dying on the coasts of Great Britain (Bourne and Mead 1969) or in seabirds in the Baltic (Jensen et al. 1969). The levels are much higher than, for example, those found in the Adelie Penguin, *Pygoscelis adeliae* (Sladen et al. 1966, Tatton and Ruzicka 1967), but they approximate those recorded for the Skua, *Catharacta skua*. The PCB level in the fat of albatrosses tends to parallel that for DDE, as suggested by Peakall and Lincer (1970) for other species, but Peakall's and Lincer's view that PCBs are "not carried quite so readily to remote areas" must be questioned.

The presence of man-made compounds in these albatrosses demonstrates pollution of the pelagic North Pacific. Although the contaminants may originate on a worldwide basis, and be distributed globally, the heavily populated and industrialized shores of Japan and western North America, and to a lesser extent the eastern islands of Hawaii, probably contribute the most pollutants to this region. Residues originating in Japan are swept eastward by prevailing winds and the Oyashio and Kuroshio

water currents into the primary albatross-feeding grounds, between lat. 30° and 45° N and long. 140° and 160° E (Fisher and Fisher 1972). Part of the eastward-trending North Pacific Current turns southward between long. 150° to 160° W and washes the eastern Hawaiian Islands. Materials added here are transported westward along the north side of the westward-trending Equatorial Current until the latter joins the Kuroshio Current near 20° or 25° N and 140° E. North American wastes move westward to the albatross-feeding grounds in two ways: (1) a counterclockwise gyre of water in the Gulf of Alaska mixes with the North Pacific Current in the neighborhood of 45° to 50° N and 150° to 160° W; and (2) the southward-trending California Current turns west at about 20° to 30° N to contribute to the clockwise Hawaiian Gyre and to the westward current, eventually contributing to the Kuroshio Current.

Another source of pelagic pollution is waste emitted from ships and planes. Risebrough and Brodine (1970: 18, 24) suggested that PCB residues may escape to the environment from hydraulic systems. Fuel wastes, garbage, cleansers, etc., are also avenues of contamination by man's transport vehicles. The Great Circle Route, used by ships and planes in most non-stop crossings of the North Pacific, traverses virtually the entire length of the primary albatross feeding area, an area which also has the greatest concentration of commercial fishing boats. The apparent significance of this source is emphasized in the interspecific differences in amounts of residues found, although the possibility of interspecific differences in enzyme systems affecting the residues cannot be denied. Ship-following and scavenging Black-footed Albatrosses exhibited residual levels of chemicals (except for DDT and dieldrin) two to four times greater than nonscavenging Laysan Albatrosses.

Corroborative of the view that scavenging may increase residues are the findings in Antarctic penguins and skuas (Tatton and Ruzicka 1967). Skuas are partly scavengers and have levels of DDE and DDT several times greater than those found in penguins; this may be related to a further concentration of DDE and DDT by skuas which feed seasonally on penguins.

Residues in the Laysan Albatross probably represent materials formerly incorporated in lower trophic levels. Although a similar level of residues in the Black-footed Albatross may accumulate from the same food sources, additional quantities probably originate elsewhere than in the oceanic food web. A garbage scow dumps offshore the refuse from the mess halls and shops of the Naval Station at Midway. Thus, these Black-footed Albatrosses may have greater access to polluted materials than that typical for the species as a whole. This adventitious source of food, and contaminants, could be disastrous. If albatrosses, with their short egg-laying period, stop ovulating after only a single heavy dose of Aroclor 1254 as demonstrated for the Coturnix Quail (*Coturnix coturnix*) (Peakall and Lincer 1970), or delay ovulation as shown in the Sharp-tailed Finch, *Lonchura striata* (Jefferies 1967), contaminated food near the breeding grounds could disrupt the breeding of the entire colony.

Further, susceptibility to poisoning by the residues may increase as seasonal loss of fat occurs, as shown for *Molothrus ater* (Stickel and Stickel 1969) and Robins, *Turdus migratorius* (Hunt 1969). The rate of fat loss exceeds the rate of pesticide elimination, at least in penguins and rats (Sladen et al. 1966, Dale et al. 1962); consequently, the amount of residue relative to body weight increases. Breeding albatrosses show major weight losses during reproduction (Fisher 1967), and breeders are most apt to feed repeatedly on these constant, nearby sources.

Greater accumulations can be expected. These albatrosses are long-lived and they feed at the top of their ecosystem. Much of the contamination may not yet have reached the higher trophic levels; it may still be increasing in marine phytoplankton, for example (Cox 1970). And some Black-footed Albatrosses already carry residues half as great as those deemed responsible for the declining reproduction in a not-too-distant relative, the Bermuda Petrel, *Pterodroma cahow* (Wurster and Wingate 1968).

Egg breakage has not increased and DDE levels, known to have an effect on shell thickness (Anderson et al. 1969), are relatively low. The larger residues to be expected may lead to reduced eggshell weight, as reported, for

example, in the following species: Japanese Quail, *Coturnix coturnix* (Peakall and Lincer 1970, Bitman et al. 1970); Mallard Ducks, *Anas platyrhynchos* (Peakall and Lincer 1970, Lehner and Egbert 1969, Heath et al. 1969); Cormorants, *Phalacrocorax auritus* (Anderson et al. 1969); Pelicans, *Pelecanus* sp. (Anderson et al. 1969, Blus 1970, Blus et al. 1971); Peregrine Falcons, *Falco peregrinus* (Anderson and Berger 1970); and Sparrow Hawks, *Falco sparverius* (Porter and Wiemeyer 1969).

Although decreased shell weight of Black-footed Albatross eggs was not apparent between 1912 and 1969, the observed 5 percent decrease between 1959 and 1969 is not necessarily contradictory. The eggs from 1912 had been incubated for some time, and shell weights may decrease 2 to 3 percent with incubation. The December 1913 eggs of the Laysan were also lighter than the November 1959 eggs ($P = < 0.05$). However, even if an actual shell weight 2 to 3 percent greater than shown for the 1912-1913 samples is conceded, it appears unlikely that significant decreases have occurred.

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